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**DETAILED DESCRIPTION**

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[Detailed Description of the Invention]

[0001]

[Industrial Application]Especially this invention relates to the manufacturing method of the field emission type cold cathode which has an emitter of a carbon film, a gate, and an insulator layer, and has an emitter of needlelike structure about the manufacturing method of field emission type cold cathode.

[0002]

[Description of the Prior Art]In recent years, field emission type cold cathode attracts attention as an electron gun for a thin display. What carries out electron emission by the electric field generated by applying voltage to a gate electrode as conventional field emission type cold cathode from the tip of the cone type emitter produced with silicon, molybdenum, etc. was in use. In this field emission type cold cathode, voltage lowering and high integration have been performed in the gate the thing of an emitter formed very much in the neighborhood, and by carrying out minuteness making of the emitter.

[0003]These days, using as an emitter the diamond system carbon films (a diamond, diamondlike carbon, etc.) in which carrying out electron emission from the low voltage is known has been proposed. By using such a material, it can be possible now to carry out electron emission with a plateau diaphragm. A voltage lowering and current control disposition top can be attained by having a gate for pulling out an electron near the emitter. By using this cold cathode, a process can be simplified and it is expected that the display of a big screen will be easily producible.

[0004]The cold cathode using the diamond which has a gate electrode is proposed, for example by JP,10-40805,A. The sectional view of this cold cathode is shown in drawing 4. By this method, after patterning the conductive layer and diacid-ized silicon which were formed on the substrate, in the state where resist remains, the solution, in which mean particle diameter

contains a diamond with a particle state of 0.2 micrometer or less is applied on a substrate, and is dried. If resist is removed, diamond particles remain only on the conductive layer. On this diamond particle, a diamond phase is formed with a vapor phase synthetic method etc. The aluminum film used as a gate is formed in the last. A formation method is not described. This cold cathode is checking electron emission with the impressed electromotive force 30V. [0005]

[Problem(s) to be Solved by the Invention]It is how when producing the field emission type cold cathode of a carbon film which has a gate, a problem drops threshold voltage, and it raises [ how ] emission current density. In the example proposed by JP,10-40805,A, electron emission is checked from low voltage called 30V using the thing which laminates diamond particles or it to an emitter, and made diamond particles laminate a diamond layer further with a vapor phase synthetic method etc. However, since there was distribution of diamond particles, that an emission point becomes sparse and raises current density had a limit. Since it had proposed making the rear gate hole which formed the emitter by the conventional example as another problem, what is called an eye gap phenomenon in which it was necessary to use photolithography technique and the position of an emitter pattern and a gate hole shifted may have happened. [0006]

[Means for Solving the Problem]What is necessary is just to make electron emission easy to make a gate into needlelike projection structure for the whole surface of a carbon film or a carbon film of an emitter which it forms in the neighborhood very much and is an emitter further, to raise field intensity, and to carry out, in order to solve the above-mentioned technical problem. A gate film is patterned and a direction which forms a carbon film without finally using photolithography technique can simplify a process. [0007]

Then, in a manufacturing method of field emission type cold cathode which has an insulator layer with which a gate and an emitter which were formed so that an emitter of a carbon film and it might be surrounded according to this invention, and a gate are insulated electrically, After growing up a carbon film into the whole surface, a carbon film formed on a gate at the time of emitter membrane formation is removed using hydrogen plasma treatment, and a manufacturing method of field emission type cold cathode making the emitter surface into needlelike projection structure simultaneously is obtained. [0008]

A gate which according to this invention was formed so that an emitter of a carbon film and it might be surrounded, A process of being a manufacturing method of field emission type cold cathode which has an insulator layer which insulates a gate with an emitter electrically, and forming an insulator layer and a gate on a substrate at this order, A process of removing said gate and an insulator layer selectively simultaneously, and a process which grows up a carbon film into after an appropriate time on the whole surface, A manufacturing method of

field emission type cold cathode including a process of making into needlelike projection structure the emitter surface which is a carbon film on said substrate is obtained at the same time it removes a carbon film on said gate film using hydrogen plasma treatment.

[0009]In a manufacturing method of field emission type cold cathode which has an insulator layer with which a gate and an emitter which were formed so that an emitter of a carbon film and it might be surrounded according to this invention, and a gate are insulated electrically, After growing up a carbon film into the whole surface, a carbon film formed on a gate at the time of emitter membrane formation is removed using oxygen plasma treatment, and a manufacturing method of field emission type cold cathode making the emitter surface into needlelike projection structure using hydrogen plasma treatment further is obtained.

[0010]A gate which according to this invention was formed so that an emitter of a carbon film and it might be surrounded, A process of being a manufacturing method of field emission type cold cathode which has an insulator layer which insulates a gate with an emitter electrically, and forming an insulator layer and a gate on a substrate at this order, A process of removing said gate and an insulator layer selectively simultaneously, and a process which grows up a carbon film into after an appropriate time on the whole surface, A manufacturing method of field emission type cold cathode including a process of removing a carbon film formed on a gate at the time of emitter membrane formation, and a process of making into needlelike projection structure the emitter surface which is a carbon film on a substrate using hydrogen plasma treatment, using oxygen plasma treatment is obtained.

[0011]In a manufacturing method of field emission type cold cathode which has an insulator layer with which a gate and an emitter which were formed so that an emitter of a carbon film and it might be surrounded according to this invention, and a gate are insulated electrically, After growing up a carbon film into the whole surface, a carbon film formed on a gate at the time of emitter membrane formation is removed using hydrogen plasma treatment, and a manufacturing method of field emission type cold cathode making an emitter into needlelike projection structure simultaneously is obtained.

[0012]A gate which according to this invention was formed so that an emitter of a carbon film and it might be surrounded, A process of being a manufacturing method of field emission type cold cathode which has an insulator layer which insulates a gate with an emitter electrically, and forming an insulator layer and a gate on a substrate at this order, A process of removing said gate and an insulator layer selectively simultaneously, and a process which grows up a carbon film into after an appropriate time on the whole surface, A manufacturing method of field emission type cold cathode including a process of making into needlelike projection structure an emitter which is a carbon film on said substrate is obtained at the same time it removes a carbon film on said gate film using hydrogen plasma treatment.

[0013]In a manufacturing method of field emission type cold cathode which has an insulator

layer with which a gate and an emitter which were formed so that an emitter of a carbon film and it might be surrounded according to this invention, and a gate are insulated electrically, After growing up a carbon film into the whole surface, a carbon film formed on a gate at the time of emitter membrane formation is removed using oxygen PUZUMA processing, and a manufacturing method of field emission type cold cathode making an emitter into needlelike projection structure using hydrogen plasma treatment further is obtained.

[0014]A gate which according to this invention was formed so that an emitter of a carbon film and it might be surrounded, A process of being a manufacturing method of field emission type cold cathode which has an insulator layer which insulates a gate with an emitter electrically, and forming an insulator layer and a gate on a substrate at this order, A process of removing said gate and an insulator layer selectively simultaneously, and a process which grows up a carbon film into after an appropriate time on the whole surface, A manufacturing method of field emission type cold cathode including a process of removing a carbon film formed on a gate at the time of emitter membrane formation, and a process of making into needlelike projection structure an emitter which is a carbon film on a substrate using hydrogen plasma treatment, using oxygen plasma treatment is obtained.

[0015]

[Embodiment of the Invention]Below, the example of a graphic display of the details of this invention explains. Drawing 1 is a sectional view showing the field emission type cold cathode used as the first example of this invention, and identical codes show drawing 4 and an equivalent portion. The main cooling negative pole is provided with the following.

It is the substrate 1 as main component part.

The carbon film 2 used as the emitter which carries out electron emission.

The gate film 3 for carrying out electron emission.

Insulator layer 4.

The surface of the carbon film used as an emitter is covered by needlelike projection structure with an acute tip. Needlelike projection structure serves as the conical shape or the shape of a pyramid which has the distance across vee of 200 nm from 1 nm, and height is 1 micrometer from 10 nm. Since the tip is acute, it is easy to carry out electric field concentrates, and electron emission is obtained from the low voltage. This needlelike density is 25-piece  $[\text{micrometer}]^2$  - 1 million-piece  $[\text{micrometer}]^2$ .

[0016]Drawing 2 shows one of the processes for producing the first example of this invention shown in drawing 1. As shown in drawing 2 (a), the gate film 3 of 4 or 200 nm of insulator layer thickness of 1-micrometer thickness is first formed on the substrate 1. After patterning the gate hole of the diameter of 1 micrometer using photolithography technique, where the resist 5 for the photolithography concerned is attached, It ultrasonicates in ethyl alcohol containing diamond particles (particle diameter of 1 micrometer or less), and the diamond particles 6 are

made to adhere to a substrate face sparsely (drawing 2 (b)).

[0017]The resist 5 is removed and the back forms about 500 nm of diamond system carbon films on condition of the total gas pressure 5 - 10Torr with a hot filament CVD method the substrate temperature of about 600 \*\*, and methane / hydrogen ratio 50-75%. Then, although the diamond system carbon film 7 grows on a substrate, on the gate film 3, the graphite system carbon film 8 is thinly formed by thickness of 100 nm or less (drawing 2 (c)). By making it generate with the output of about 500 W, and finally, carrying out the surface treatment of the ECR plasma which impressed the magnetic field of about 850 to 900 G, and about 2.5-GHz microwave under the hydrogen gas 10-4 - the pressure of 10-3Torr, The graphite system carbon film 8 on the gate film 3 can be removed easily, the surface of the diamond system carbon film 7 can be simultaneously made into needlelike projection structure, and the field emission type cold cathode of this invention can be produced (drawing 2 (d)).

[0018]If this process is used, the field emission type cold cathode which has an emitter which consists of a carbon film which has needlelike projection structure in the surface can be produced, and voltage lowering and the densification of current will become possible compared with a conventional example. The photolithography technique also of the worries about an eye gap of the gate which became one use and became a problem by the conventional example, and an emitter etc. is lost, and process nearby simplification is carried out. It is effective in the graphite system carbon film 8 on the gate film 3 being simultaneously [ with the processing for needlelike projection structure ] removable.

[0019]The second example of this invention is shown below. Drawing 3 is a sectional view showing the field emission type cold cathode of this second example. Although the same process as the first above-mentioned example is performed and cold cathode is produced, hydrogen plasma treatment in the same conditions as the first example can be made slightly longer, the whole diamond system carbon film can be made into needlelike structure, and the field emission type cold cathode of this invention can be produced.

[0020]If this process is used, the field emission type cold cathode which has an emitter which consists of a carbon film of needlelike projection structure can be produced, and voltage lowering and the densification of current will become possible compared with a conventional example. Compared with the first example, since there is no carbon layer to needlelike structure, electronic supply from a substrate is performed more smoothly, and voltage lowering can be carried out more. The photolithography technique also of the worries about an eye gap of the gate which became one use and became a problem by the conventional example, and an emitter etc. is lost, and process nearby simplification is carried out. It is effective in the graphite system carbon film 8 on the gate film 3 being simultaneously [ with the processing for needlelike projection structure ] removable.

[0021]The third example of this invention is shown below. After performing the same process

as the first example of the above until it forms the diamond system carbon film 7, under the oxygen gas 10-5 - the pressure of 10-4Torr, The ECR plasma which impressed the magnetic field of about 850 to 900 G and about 2.5-GHz microwave is generated with the output of about 500 W, and the graphite system carbon film 8 which has adhered on the gate film 3 is removed by carrying out a surface treatment. The ECR plasma which furthermore impressed the magnetic field of about 850 to 900 G and about 2.5-GHz microwave under the hydrogen gas 10-4 - the pressure of 10-3Torr is generated with the output of about 500 W, By carrying out a surface treatment, the surface of a diamond system carbon film can be made into needlelike structure, and the field emission type cold cathode of this invention can be produced.

[0022]If this process is used, the field emission type cold cathode which has an emitter which consists of a carbon film which has needlelike projection structure in the surface can be produced, and voltage lowering and the densification of current will become possible compared with a conventional example. The photolithography technique also of the worries about an eye gap of the gate which became one use and became a problem by the conventional example, and an emitter etc. is lost, and process nearby simplification is carried out. Time to remove a graphite system carbon film can be shortened by using oxygen plasma treatment.

[0023]The fourth example of this invention is shown below. After performing the same process as the third example until it removes a graphite system carbon film, hydrogen plasma treatment in the same conditions as the third example can be performed for a long time, the whole diamond system carbon film can be made into needlelike structure, and the field emission type cold cathode of this invention can be produced.

[0024]If this process is used, the field emission type cold cathode which has an emitter which consists of a carbon film of needlelike projection structure can be produced, and voltage lowering and the densification of current will become possible compared with a conventional example. Compared with the third example of the above, since there is no carbon layer to needlelike structure, electronic supply from a substrate is performed more smoothly, and voltage lowering can be carried out more. The photolithography technique also of the worries about an eye gap of the gate which became one use and became a problem by the conventional example, and an emitter etc. is lost, and process nearby simplification is carried out. Graphite system carbon film time can be shortened by using oxygen plasma treatment.

[0025]The fifth example of this invention is shown below. The process by a place of making diamond particles adhering to a substrate face sparsely is the same as the first example of the above. After removing resist, with a hot filament CVD method, if about 500 nm of diamond films are formed on condition of the total gas pressure 20 - 60Torr the substrate temperature of about 600-850 \*\*, and methane / hydrogen ratio 1-10%, a film will grow on a substrate, but. On

a gate film, a graphite system carbon film is formed thinly. Finally the ECR plasma which impressed the magnetic field of about 850 to 900 G and about 2.5-GHz microwave under the hydrogen gas  $10^{-4}$  - the pressure of  $10^{-3}$ Torr is generated with the output of about 500 W, By carrying out a surface treatment, the graphite system carbon film on a gate film can be removed, can make the surface of a diamond film needlelike projection structure simultaneously, and can produce the field emission type cold cathode of this invention.

[0026]If this process is used, the field emission type cold cathode which has an emitter which consists of a carbon film which has needlelike projection structure in the surface can be produced, and voltage lowering and the densification of current will become possible compared with a conventional example. The photolithography technique also of the worries about an eye gap of the gate which became one use and became a problem by the conventional example, and an emitter etc. is lost, and process nearby simplification is carried out.

[0027]The sixth example of this invention is shown below. The same process as the fifth example of the above is performed until it forms a diamond film. Hydrogen plasma treatment in the same conditions as the fifth example can be made slightly longer, the whole diamond film can be made into needlelike projection structure, and the field emission type cold cathode of this invention can be produced.

[0028]If this process is used, the field emission type cold cathode which has an emitter which consists of a carbon film of needlelike projection structure can be produced, and voltage lowering and the densification of current will become possible compared with a conventional example. Compared with the fifth example, since there is no carbon layer to needlelike structure, electronic supply from a substrate is performed more smoothly, and voltage lowering can be carried out more. The photolithography technique also of the worries about an eye gap of the gate which became one use and became a problem by the conventional example, and an emitter etc. is lost, and process nearby simplification is carried out.

[0029]The seventh example of this invention is shown below. The same process as the fifth example of the above is performed until it forms a diamond film. Next, the carbon film which has adhered on a gate is removed by making it generate with the output of about 500 W, and carrying out the surface treatment of the ECR plasma which impressed the magnetic field of about 850 to 900 G, and about 2.5-GHz microwave under the oxygen gas  $10^{-5}$  - the pressure of  $10^{-4}$ Torr. By making it generate with the output of about 500 W, and carrying out the surface treatment of the ECR plasma which impressed the magnetic field of about 850 to 900 G, and about 2.5-GHz microwave under the hydrogen gas  $10^{-4}$  - the pressure of  $10^{-3}$ Torr, The surface of a diamond film can be made into needlelike structure, and the field emission type cold cathode of this invention can be produced.

[0030]If this process is used, the field emission type cold cathode which has an emitter which

consists of a carbon film which has needlelike projection structure in the surface can be produced, and voltage lowering and the densification of current will become possible compared with a conventional example. The photolithography technique also of the worries about an eye gap of the gate which became one use and became a problem by the conventional example, and an emitter etc. is lost, and process nearby simplification is carried out. Time to remove a graphite system carbon film can be shortened by using oxygen plasma treatment.

[0031]The eighth example of this invention is shown below. The same process as the seventh example of the above is performed until it removes the carbon film which has adhered on a gate. Finally hydrogen plasma treatment in the same conditions as the seventh example can be performed for a long time, the whole diamond film can be made into needlelike structure, and the field emission type cold cathode of this invention can be produced.

[0032]If this process is used, the field emission type cold cathode which has an emitter which consists of a carbon film of needlelike projection structure can be produced, and voltage lowering and the densification of current will become possible compared with a conventional example. Compared with the seventh example, since there is no carbon layer to needlelike structure, electronic supply from a substrate is performed more smoothly, and voltage lowering can be carried out more. The photolithography technique also of the worries about an eye gap of the gate which became one use and became a problem by the conventional example, and an emitter etc. is lost, and process nearby simplification is carried out. Graphite system carbon film time can be shortened by using oxygen plasma treatment.

[0033]

[Effect of the Invention]As explained above, according to this invention, it is effective in the field emission type cold cathode which carries out electron emission by high density from the gate which carries out electron emission from an emitter, and the low voltage which has an emitter of a carbon film being producible. This is because the field intensity to the tip of an emitter becomes high and the detailed needlelike emitter can moreover be uniformly formed in the emitter region whole surface making into needlelike projection structure with an acute tip the emitter which consists of carbon films, and by [ its ] forming a gate in the neighborhood very much.

[0034]According to this invention, the field emission type cold cathode which has an emitter of a gate and a carbon film is easily producible by accepting a photolithography once and using it. The process of making removal, and a diamond system carbon film or a diamond film of the graphite system carbon film deposited on the gate into needlelike structure can be simultaneously performed by using hydrogen plasma treatment especially.



[Translation done.]